TESTS OF FIRE-RETARDANT CHEMICALS AT PLUM CREEK

BY JAMES B. DAVIS, DEAN L. DIBBLE, KENNETH L. SINGER

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1962

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FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE

Pacific Southwest Forest and Range Experiment Station
Arcadia Equipment Development Center
Region 5

TESTS OF FIRE-RETARDANT CHEMICALS AT PLUM CREEK

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In June 1962, five fire-retardant chemicals that had performed well in the laboratory were field-tested on small controlled fires in natural brush fuels at Plum Creek near Red Bluff, California. These tests, sponsored by the California Air Attack Coordinating Committee (CALAIRCO), supported laboratory findings and showed that viscous or thickened solutions of diammonium phosphate and ammonium sulphate are probably superior to fire retardants now in operational use.

Diammonium phosphate and ammonium sulphate are not new to forest fire control work. Both chemicals have been tested in an unthickened state for many years with varying degrees of success (Barrett 1931; Serebrennikov 1934) and have rated high on lists of fire retardants (Truax 1939). They generally worked well on fuel types and burning conditions found in the southeastern United States (Johansen 1959). But they proved ineffective on heavy fuels and hot fires in the West,[1/] probably because too little material stuck to the fuel.

Laboratory tests have indicated, however, that 20 times more chemical retardant can be retained on vertical fuel surfaces if the solution is thickened (Langguth 1961; Davis et al. 1962). Viscous or thickened diammonium phosphate (DAP) has

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1/ Firestop. Field tests of chemicals for forest fire control. 1954. (Unpublished report on file at Pacific Southwest Forest and Range Experiment Station, U. S. Forest Service, Berkeley 1, California.)

proved to be an effective fire retardant in various field tests (Pacific Southwest Forest and Range Experiment Station 1960; Maul 1961; Phillips 1961; Brown 1962).

In March of 1962, the facilities of the forest fire laboratory at Missoula, Montana, were used to test various retardants that had shown promise in preliminary studies (Hardy et al. 1962). The laboratory tests and the Plum Creek tests described in this report are part of a standard system for the evaluation and development of firefighting chemicals (Hardy et al. 1962, pp. 3-4). The system consists of (a) setting performance requirements, (b) initial screening of chemicals, (c) laboratory tests of chemicals, (d) laboratory fire tests, (e) field tests, (f) operational tests, (g) engineering of equipment, and (h) preparation of application guides.

FIRE RETARDANT CHEMICALS

The five fire-retardant chemicals tested were: (a) algin-diammonium phosphate, (b) sodium carboxy methyl cellulose-diammonium phosphate, (c) sodium pectin-diammonium phosphate, (d) ammonium pectin-diammonium phosphate, and (e) Fire-Trol. The tests also included borate and algin-gel for purposes of comparison.

DAP is nontoxic to plants or animals and, since it is readily soluble, presents no abrasion problem. It is corrosive to metals, including aluminum, copper, and several of their alloys, but inhibits rust on mild steel.

Viscous DAP solutions retard fire through chemical action rather than through cooling with water. Thus their effectiveness does not depend upon the water-holding capacity of the solution, but rather upon the amount of dry DAP coating the fuel.

Algin-diammonium phosphate.--DAP solutions thickened with sodium alginate adhere in thick layers to foliage and stems of vegetation. The algin can be readily mixed in batch-type mixers used at airports; the mixture reaches its peak viscosity within a few seconds. DAP is then added and immediately goes into solution. Algin-DAP can also be pre-blended. The cost should be about 20 cents per gallon.

CMC-diammonium phosphate.--Sodium carboxy methyl cellulose (CMC)—manufactured from wood, cotton, and other cellulose-based material—is an organic polymer that also mixes with DAP. It forms a thick fire-retardant coating on vegetation. DAP can either be added to a solution of CMC or the mixture can be pre-blended and bagged by the manufacturer. The cost of CMC-DAP should be about 14 cents per gallon.

Sodium pectin-diammonium phosphate.--Sodium pectin, produced as a byproduct of the citrus industry, appears to be a good thickener. It forms a viscous solution with water, and then quickly progresses to the consistency of heavy gravy when combined with DAP. The resulting gel clings to vegetation readily. It holds a large quantity of water initially, but eventually dries to a fire-retardant coating. The sodium pectate must be mixed with water before DAP is added. The cost is from 12 to 15 cents per gallon.

Ammonium pectin-diammonium phosphate.--The properties of this chemical retardant are quite similar to those of sodium pectin-DAP. However, the powdered ammonium pectate and DAP can be pre-blended and bagged together. The cost also ranges from 12 to 15 cents per gallon.

Fire-Trol.--Fire-Trol is a combination of ammonium sulphate and attapulgite clay. This material is formulated and blended by the manufacturer. Like DAP, ammonium sulphate

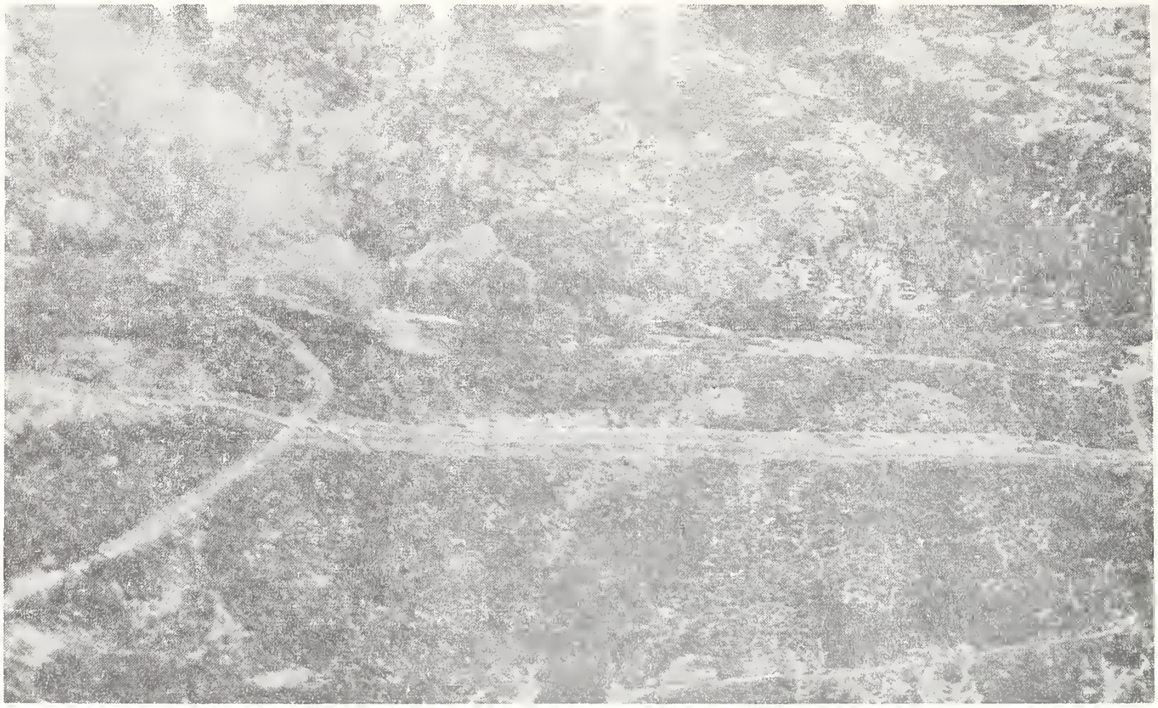


Figure 1. --Aerial view shows the Plum Creek test site and preliminary fire breaks.

Figure 2. --Heavy brush grew on most of the test site. It weighed from 40 to 45 tons per acre.

Figure 3. --Light brush occupying the poorer sites weighed from 12 to 15 tons per acre.

ranks near the top of most lists of fire-retardant chemicals. Attapulgite, a clay used in salt water oil drilling operations, thickens the ammonium sulphate solution to a thick, stable slurry. The slurry initially holds a large quantity of water. The 15 percent ammonium sulphate content[2/] remains an effective fire retardant when the slurry dries. High sheer impellers are required to properly mix Fire-Trol. Without an inhibitor, Fire-Trol corrodes copper, brass, and mild steel. The cost of Fire-Trol should be from 12 to 15 cents per gallon.

THE PLUM CREEK TEST SITE

The test area is a rolling, brush-covered ridge that ranges in elevation from 2,450 to 2,650 feet (fig. 1).

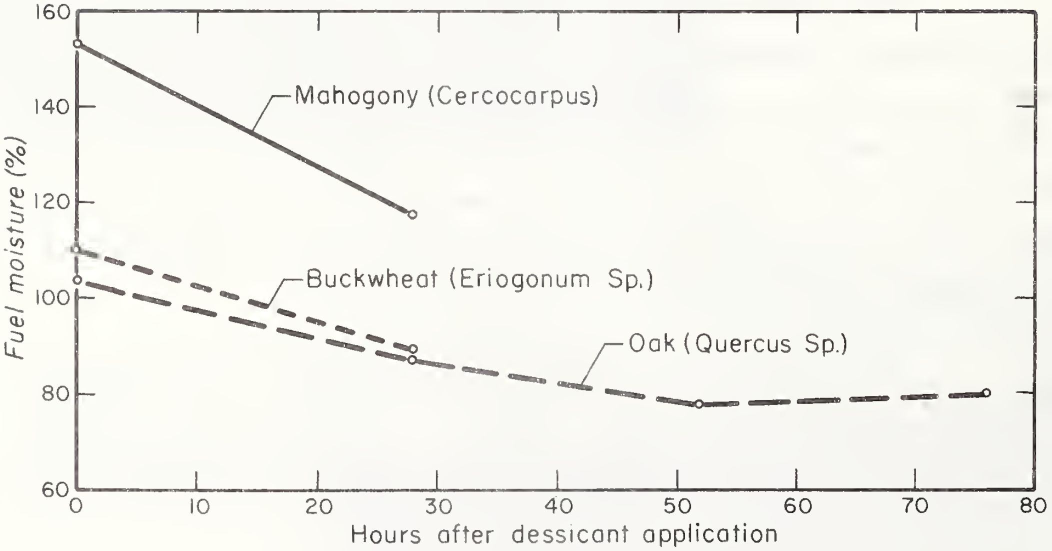
The vegetation consisted of two distinct groupings. The first, a mixed stand of oak (Quercus dumosa, Q. chrysolepis, and Q. wislizeni), ceanothus (Ceanothus sp.), and mountain mahogany (Cercocarpus betuloides), grows on ridge tops, occupying the largest portion of the test area. This combination averaged 8 to 10 feet in height, weighed from 40 to 45 tons per acre, and contained 10 to 15 percent dead material (fig. 2).

The other group of vegetation on the test site consisted of buckwheat (Eriogonum sp.) and mountain mahogany in the draws and saddles, which were the poorer sites. The fuel weight averaged from 12 to 15 tons per acre. About 20 to 30 percent of the weight in this vegetation group was made up of dead material, and frequent openings were generally filled with a light stand of dry annual grass (fig. 3).

2/ During the tests, the predetermined mixture of Fire-Trol was found difficult to pump. To reduce the viscosity, the material was used slightly diluted but with additional ammonium sulphate added to maintain the 15 percent ammonium sulphate level.

Figure 4.--Green fuel moisture content was determined by reacting a weighed sample of brush with carbide in a closed vessel and measuring the resultant acetylene gas pressure.

Figure 5.--Reduction in green fuel moisture over a four-day period after desiccant application.



TEST PROCEDURES

DESICCATING THE TEST AREA

The original plan was to drop retardants from air tankers on brush in its natural condition and then burn the brush after the retardant had dried 3 hours and 24 hours. But because of late spring rains and cool weather, fuel moisture in the green brush was much higher than expected. To get the fuel moisture down to a level where uniform hot fires could be obtained, we decided to desiccate the area with a contact, nonselective herbicide (Arnold et al. 1951; Wagle 1961). We wanted to reduce the green fuel moisture to a level normal for midsummer without defoliating the vegetation. On June 18, 20 gallons of toxic weed oil[3/] and half a gallon of pentachlorophenol per acre were applied from the air. Ground crews observed an almost immediate drying effect. By June 20, the date of the first burn, the green fuel moisture content had been reduced to the desired level (figs. 4 and 5).

MINIMIZING WEATHER INFLUENCES

We recognized that variations in weather could drastically affect fire behavior and tried to minimize this effect by: (a) carefully observing weather conditions and conducting all test fires within a fairly standard set of burning conditions, (b) conducting all the burns for the day within as short a time interval as possible, and (c) replicating tests with each material. A fire behavior specialist from the Pacific Southwest Forest and Range Experiment Station and a meteorologist from the Redding Fire Weather Office assisted on the project. They made daily fire

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3/ Avon Annalos-II, Tidewater Oil Company.

weather forecasts for the test area (Appendix). They also were responsible for a "go" or "no go" recommendation for each day's test. Although no burns were canceled, the group did rule out the planned morning burns. Thus, all fire tests were held in the afternoon.

A record of temperature, humidity, and wind speed and direction was begun two days before the first fire and continued throughout the tests (figs. 6 and 7). Wind aloft measurements were also taken with daily balloon soundings at 1045 P.d.t. (table 1, Appendix).

MIXING AND HANDLING CHEMICALS

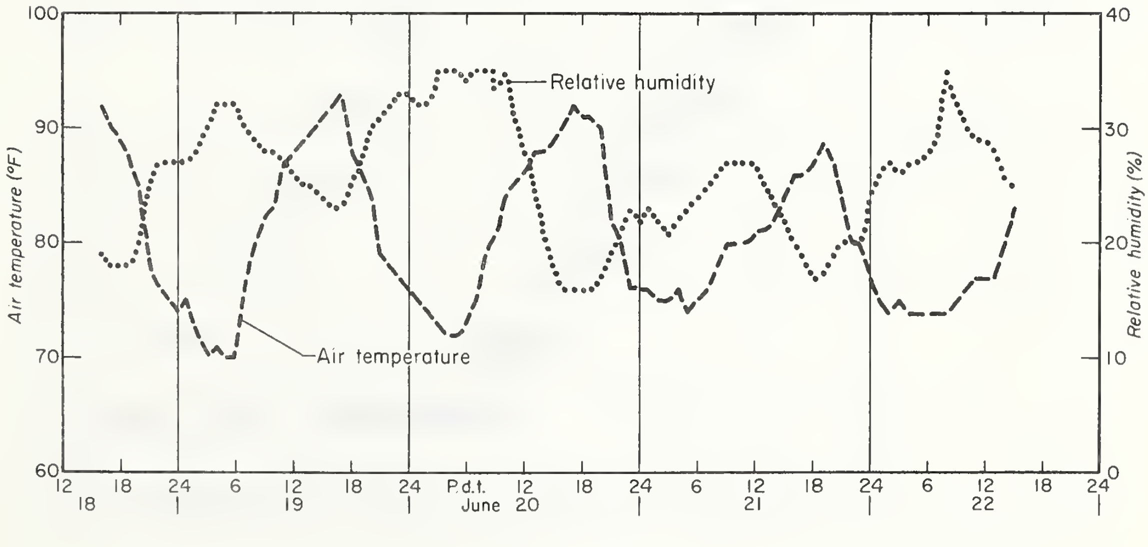
All of the chemicals were mixed in 600-gallon lots in a side-entry, batch-type mixer developed by the California Division of Forestry (fig. 8). The mixer is typical of several that the Division has installed at air facilities throughout the State, except that this unit had two special high-sheer impellers designed specifically to mix the viscosity agents.

The chemicals were mixed with water in the following proportions:

Algin DAP:	600	gallons water
	75	pounds Keltex FF
	750	pounds Diammonium Phosphate
Algin Gel:	550	gallons water
	40	pounds Keltex FF
	50	gallons water plus 4 pounds Calcium Chloride and add to above mix.
Borate:	600	gallons water
	2,400	pounds Firebrake

Figure 6.--Standard fire weather trailers were used during the test. These self-contained units can graphically record wind speed and direction, temperature, and relative humidity.

Figure 7.--Diurnal changes in temperature and relative humidity before and during the Plum Creek tests.



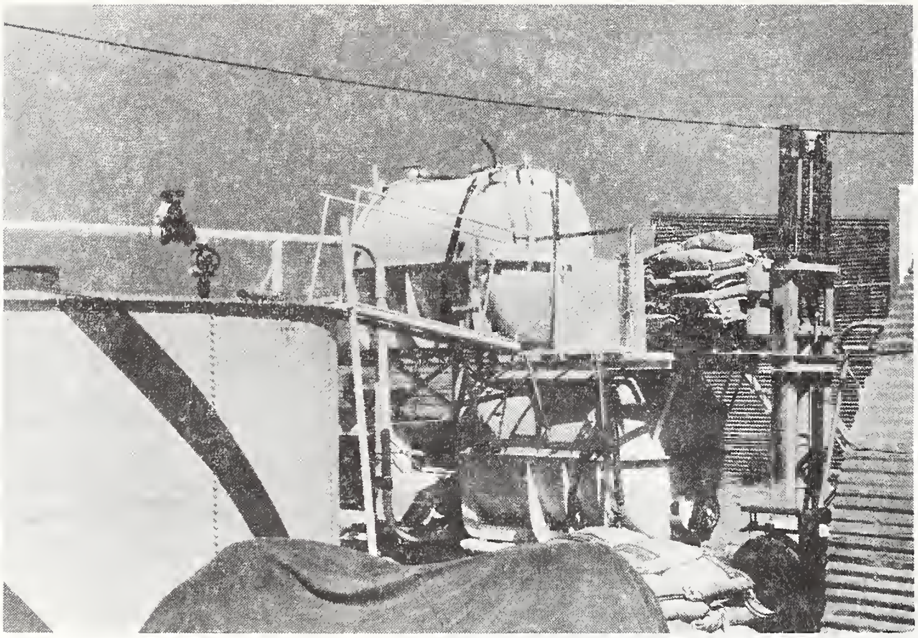


Figure 8. --Side-entry batch mixer prepared the various chemical retardants. This unit is typical of equipment installed at California Division of Forestry air facilities.

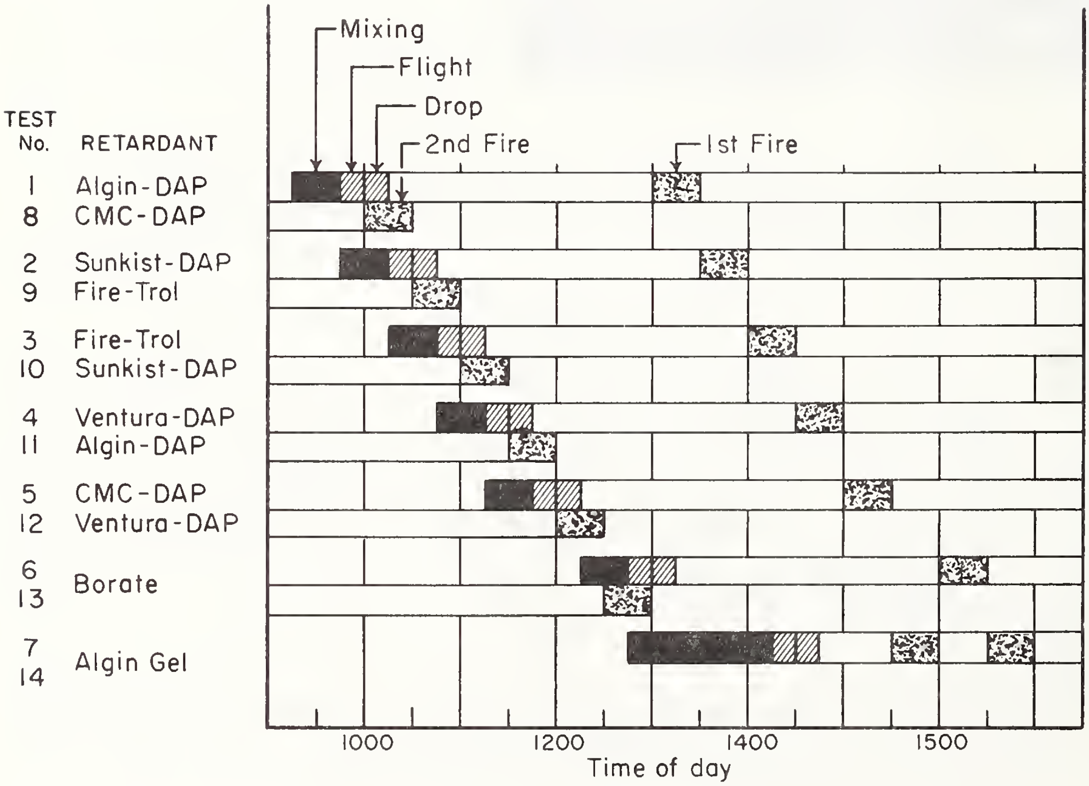


Figure 9. --Schedule of operations, 3-day test series.

CMC-DAP:	600	gallons water
	62.5	pounds Carboxymethylcellulose
	625	pounds Diammonium Phosphate
Fire-Trol:	600	gallons water
	1,480	pounds Fire-Trol
	240	pounds Ammonium Sulphate
Sodium Pectin-DAP:	600	gallons water
	200	pounds Cellupectate (Sunkist)
	6	pounds Questex
	600	pounds Diammonium Phosphate
Ammonium Pectin-DAP:	600	gallons water
	300	pounds Ammonium Pectate (Ventura)
	30	pounds Versene
	750	pounds Diammonium Phosphate

The test sequence (fig. 9) called for retardant mixing to start at 0915 P.d.t. Mixing equipment, filling lines, and the like were to be flushed out and a new mixture prepared at half-hour intervals. Thirty minutes was allowed for the aircraft's round trip to and from the drop area, including all takeoff, drop, landing, and taxi time.

The aircraft was flagged into the preselected target area, the drop was made, and the flagging crew immediately set up the next target (fig. 10). The operation was controlled by radio as much as possible. Slight misses of the exact target area were anticipated as we had little time for dry runs by the aircraft. Each drop produced a pair of plots.

Immediately after the drop, a bulldozer prepared two 150- by 100-foot test plots so that a uniform application of retardant covered the downwind end of each plot. In this manner, openings or voids in the brush were avoided (figs. 11 and 12).

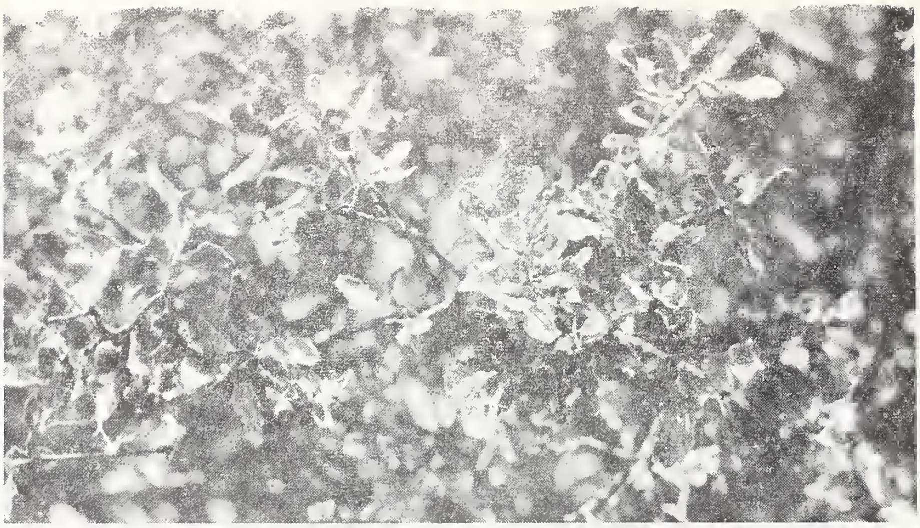


Figure 10. --Typical retardant coverage on foliage after an air drop.

Figure 11. --Plot layout after each air drop of retardants.

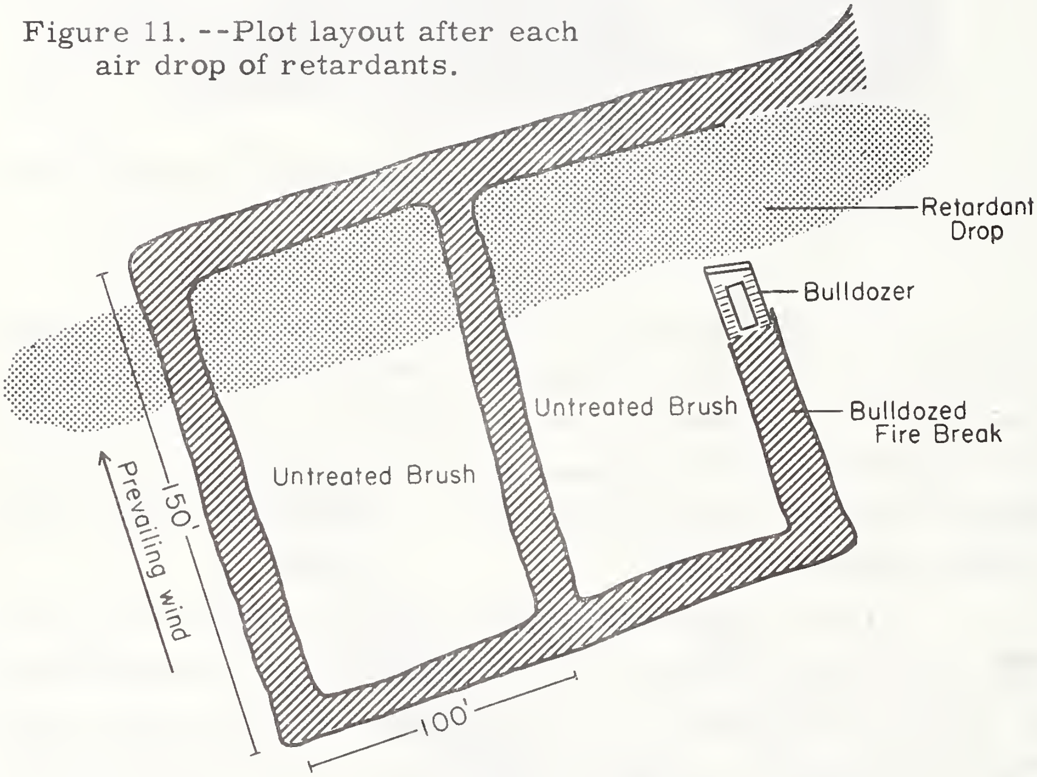


Figure 12. --A bulldozer preparing a test plot shortly after an air drop.

Figure 13.--Igniting brush along the edge of a test plot. A narrow strip along the plot edge had been sprayed with diesel oil to insure prompt and uniform ignition.

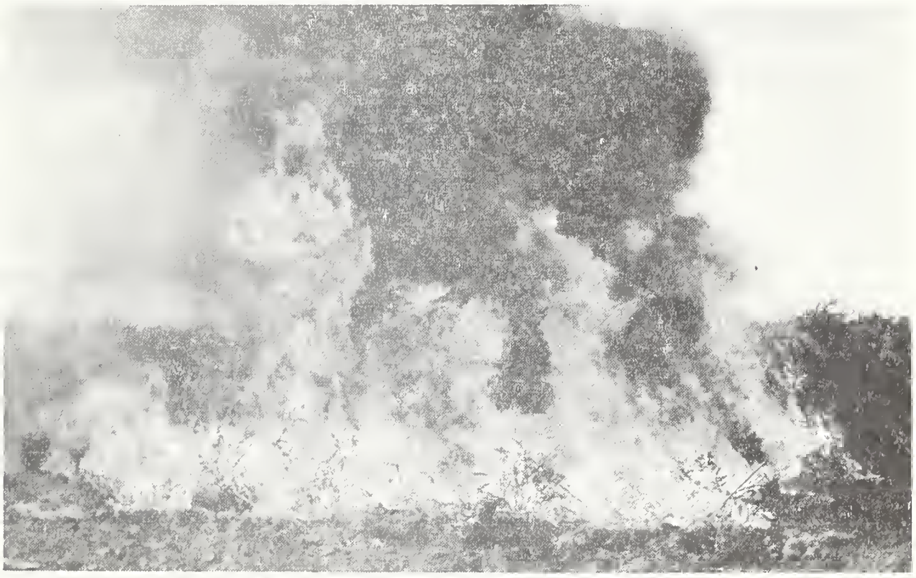


Figure 14.--Fire builds up to high intensity in the untreated portion of the plot.

Figure 15.--The fire was stopped abruptly in most cases when it reached the area treated with ammonium phosphate and sulphate retardants.

BURNING THE TEST PLOTS

We had planned to burn the 24-hour plots on the morning after the drop, but poor burning conditions in the morning caused all fires to be burned in the afternoon. On the second day both the 3-hour and the 24-hour fires of the previous day's drops were burned concurrently. All plots were ignited in as uniform a manner as possible. Burning progressed in such a way that the fire front was pulled into the retardant treated line (figs. 13, 14, and 15). A description of fire behavior was tape recorded and photographs were taken.

TEST RESULTS

MIXING TIME

Mixing time varied greatly, depending upon the quantity of material mixed per gallon, hydration time, and packaging; that is, whether materials were pre-blended or had to be added separately (table 2, Appendix). Most of the times listed in table 2 exceeded operational times because they include delays required for sampling and inspection—delays that would not occur under actual operating conditions.

Pumping the various mixtures into the air tanker proved to be somewhat more of a problem than mixing. The chemicals were pumped directly from the batch mixer to the air tanker, a distance of 200 feet, through 2 1/2-inch pipe and hose. The pumping time increased as the viscosity increased and was, in many cases, longer than the time allowable in an air tanker operation (fig. 16).

The higher viscosity retardants, such as viscous DAP, probably will require shorter loading lines and larger diameter plumbing for efficient operational use. A delay that resulted during the pumping of Fire-Trol permitted a gel to "set up" in the loading line. A subsequent mix during which no delay occurred was loaded without difficulty.

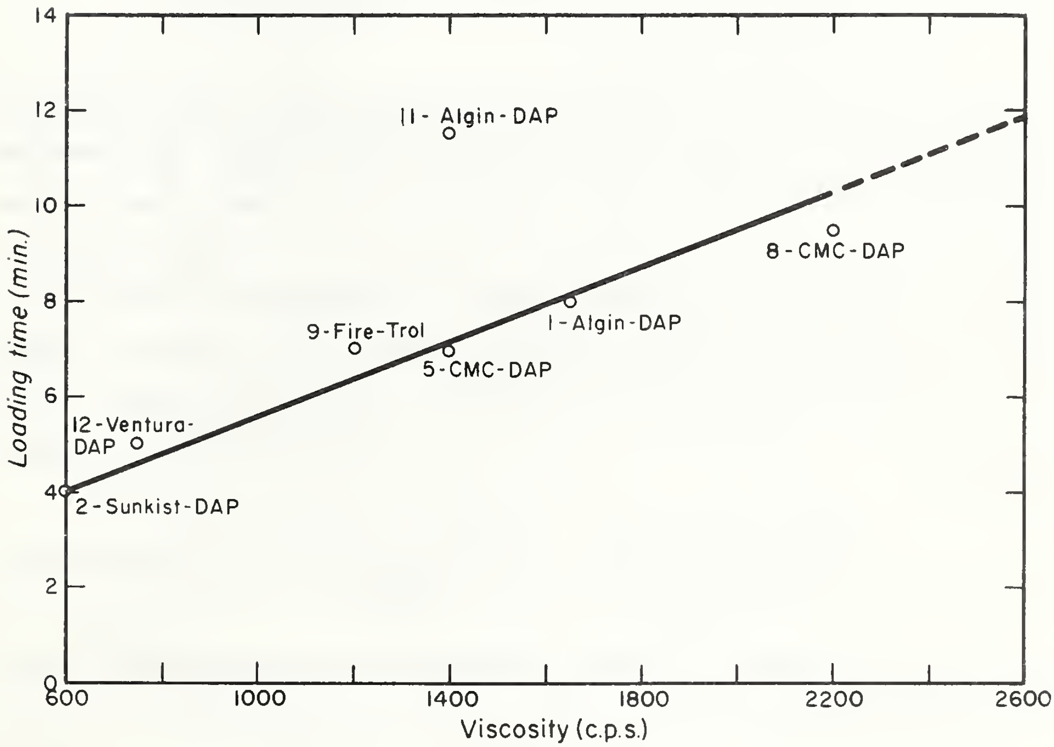


Figure 16. --Aircraft loading time increased as viscosity of retardants increased.

EFFECTIVENESS OF RETARDANT

Retardant effectiveness appeared to fall into three well-defined classes:

1. The fire was completely stopped at the edge of the retardant-treated line.
2. The fire made a deep penetration into the retardant-treated area but was eventually stopped.
3. The fire was slowed by the retardant, but eventually burned through the entire treated area.

Fuel density affected the fire behavior in the untreated portion of the test area, but the effect of this factor was reduced somewhat by desiccation and careful plot selection. The degree of slope was a minor factor as it was fairly constant and gentle. Wind was by far the greatest factor. It largely made the difference between very hot fires that hit the retardant area on a broad front and those that merely backed into the treated area. Fire intensity was rated by the evaluator in one of four relative categories:

1. High intensity.--Usually the result of a combination of dense brush and favorable wind and slope.

2. Medium intensity.--The result of either light brush or low wind velocity.

3. Low intensity.--Usually caused by a combination of light brush and low wind velocity.

4. No test.--The fires in this category backed into the retardant line against the wind.

One evaluator was used throughout the tests because the rating of fire intensity was largely a matter of personal opinion. However, during the second day a second observer assisted him in the period that both 3-hour and 24-hour tests were being conducted (table 3, Appendix).

Although the data are not suitable for statistical analysis, the effects of the various retardants were so marked that several conclusions can be made.

- In no case did a fire burn through an area treated with thickened DAP or ammonium sulphate, regardless of fire intensity.
- In 2 of the 11 cases where the fire was rated as high or medium in intensity, the fire burned into but not through the area treated with thickened DAP or ammonium sulphate.
- There appears to be no significant difference in fire retardant effectiveness between the diammonium phosphate and ammonium sulphate materials nor among the various thickeners.
- Borate stopped a high-intensity fire after 3 hours of drying, but only slowed a medium-intensity fire after 24 hours of drying.
- After 1 hour of drying, algin gel stopped one high-intensity fire; a medium-intensity fire burned into, but did not cross, a second treated area. After 3 hours of drying, algin gel held a low-intensity fire, although the fire burned into the retardant-treated area.

The results of the Plum Creek tests, when considered in the light of previous laboratory and field studies, show that thickened diammonium phosphate and ammonium sulphate retardants are probably more effective than materials now in operational use, and can be counted on to stop fires hours after application. They mix readily in existing batch-type mixers. Comparatively small quantities are required, and the cost is moderate. These retardants are not toxic to vegetation, but they are corrosive to some metals that are used in aircraft.

The next step will be operational testing of one or more of the materials from air tanker bases at several locations in the West. These tests will be followed by necessary equipment development and the preparation of application and use guides.

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APPENDIX

Table 1. --Weather conditions prevailing during each of the test fires.

Retardant and test conditions	Temperature	Humidity	Wind speed at 20 feet
	° F.	Percent	M.p.h.
Algin-DAP			
First burn, 3 hour drying	88	23	7
First burn, 24 hour drying	83	23	8
Second burn, 3 hour drying	86	20	7
Second burn, 24 hour drying	77	26	9
Algin-Gel			
First burn, 1 hour drying	89	16	9
First burn, 3 hour drying	--	--	--
Second burn, 1 hour drying	86	18	7
Second burn, 3 hour drying	86	19	5
Borate			
First burn, 3 hour drying	86	18	6
First burn, 24 hour drying	83	25	11
CMC-DAP			
First burn, 3 hour drying	91	16	4
First burn, 24 hour drying	83	23	6
Second burn, 3 hour drying	83	23	6
Second burn, 24 hour drying	79	27	8
Fire-Trol			
First burn, 3 hour drying	--	--	--
First burn, 24 hour drying	--	--	--
Second burn, 3 hour drying	84	22	6
Second burn, 24 hour drying	79	27	6
Sodium pectin-DAP			
First burn, 3 hour drying	88	20	4
First burn, 24 hour drying	84	22	8
Second burn, 3 hour drying	80	26	4
Second burn, 24 hour drying	80	26	10
Ammonium pectin-DAP			
First burn, 3 hour drying	89	18	7
First burn, 24 hour drying	85	21	6
Second burn, 3 hour drying	84	22	8
Second burn, 24 hour drying	82	25	8

Table 2.--Mixing and loading time and viscosity of chemical retardants tested.

Test Number	Retardant	Mixing time	Loading time	Viscosity
		---Minutes---		Cps.
1	Algin-DAP	8	8	1,650
2	Sodium pectin-DAP	7	4	600
3	Fire-Trol	7	(1/)	7,300
4	Ammonium pectin-DAP	5	--	1,250
5	CMC-DAP	5	7	1,400
6	Borate	--	--	750
7	Algin Gel	2.5	--	--
8	CMC-DAP	10	9.5	2,200
9	Fire-Trol	18.5	7	1,200
10	Sodium pectin-DAP	--	--	700
11	Algin-DAP	4	11.5	1,400
12	Ammonium pectin-DAP	6	5	750
13	Borate	--	--	950
14	Algin Gel	8	--	6,600

1/ The Fire-Trol "set up" during a temporary shutdown in the loading operation, and loading could not be completed.

Table 3. --Time and date, burning intensity, and drying time of each test fire effect of retardants being studied.

Retardant and test conditions	Time and date of burn	Drying time (hours and minutes)	Burning intensity	Effects of retardant
Algin-DAP				
First burn, 3 hour drying	1325, June 20	3:52	Low	Stopped fire
First burn, 24 hour drying	1427, June 21	28:34	Low	Stopped fire
Second burn, 3 hour drying	1630, June 21	4:44	Medium	Stopped fire
Second burn, 24 hour drying	1405, June 22	26:19	Medium	Stopped fire
Algin-Gel				
First burn, 1 hour drying	1550, June 20	1:25	Medium	Fire burned in
First burn, 3 hour drying	--	--	--	--
Second burn, 1 hour drying	1632, June 21	1:50	High	Stopped fire
Second burn, 3 hour drying	1705, June 21	2:23	Low	Fire burned in
Borate				
First burn, 3 hour drying	1711, June 21	4:22	High	Stopped fire
First burn, 24 hour drying	1510, June 22	26:21	Medium	Slowed
CMC-DAP				
First burn, 3 hour drying	1632, June 20	3:52	No test	Did not reach
First burn, 24 hour drying	1420, June 21	25:40	Very high	Fire burned in
Second burn, 3 hour drying	1447, June 21	4:55	Medium	Stopped fire
Second burn, 24 hour drying	1330, June 22	27:38	High	Stopped fire
Fire-Trol				
First burn, 3 hour drying	--	--	--	--
First burn, 24 hour drying	--	--	--	--
Second burn, 3 hour drying	1505, June 21	4:30	No test	Did not reach
Second burn, 24 hour drying	1345, June 22	27:10	Medium	Stopped fire
Sodium pectin-DAP				
First burn, 3 hour drying	1444, June 20	4:19	Medium	Stopped fire
First burn, 24 hour drying	1503, June 21	28:38	No test	Did not reach
Second burn, 3 hour drying	1555, June 21	4:48	Medium	Fire burned in
Second burn, 24 hour drying	1355, June 22	26:48	High	Stopped fire
Ammonium pectin-DAP				
First burn, 3 hour drying	1510, June 20	4:25	High	Stopped fire
First burn, 24 hour drying	1520, June 21	28:35	High	Burned in
Second burn, 3 hour drying	1500, June 21	2:43	Low	Stopped fire
Second burn, 24 hour drying	1444, June 22	26:27	No test	Did not reach

6/20/62 1100

Fireweather-Fire Behavior Forecast
for Plum Creek Air Tanker Tests

Forecast for afternoon of 6/20

Weather:

1 p.m.

Temperature 91°, relative humidity 24%, fuel moisture 5.5%, wind southwest 7-9 m.p.h.

Brush burning index 14, fire load index 13.

4 p.m.

Temperature 94°, relative humidity 21%, fuel moisture 5.0%, wind west 5-12 m.p.h. and gusty.

Brush burning index 17, fire load index 18.

Fire Behavior:

Conditions are marginal for good brush burning. Where fuels are dense and well distributed, good hot burns are likely. Where plots contain primarily scattered buckbrush, fire probably will not carry through the plot.

Outlook for Tomorrow:

Slight increase in wind. Temperature, humidity, and fuel moisture unchanged or slightly cooler and more moist.

C. Cole, USWB
C. Chandler, USFS

6/21/62 1100

Fireweather-Fire Behavior Forecast
for Plum Creek Air Tanker Tests

Forecast for afternoon of 6/21

Weather:

1 p.m.

Temperature 88°, relative humidity 22%, fuel moisture 5.0%, wind westerly 4-6 m.p.h.

Brush burning index 11, fire load index 12.

4 p.m.

Temperature 90°, relative humidity 18%, fuel moisture 4.5%, wind westerly 7-10 m.p.h.

Brush burning index 23, fire load index 29.

Fire Behavior:

Conditions are more favorable for hot brush burning than they were yesterday and should continue to improve through the afternoon. Fires should burn well except where fuels are light and scattered. Spotting and fire escapes are possible in late afternoon.

Outlook for Tomorrow:

2-6° cooler, humidity unchanged, wind west to southwest up to 15 m.p.h. Possibility of marine air moving into area tomorrow afternoon or evening.

C. Cole, USWB
C. Chandler, USFS

6/22/62 1100

Fireweather-Fire Behavior Forecast for Plum Creek Air Tanker Tests

Forecast for afternoon of 6/22

Weather:

1 p.m.

Temperature 80°, relative humidity 26%, fuel moisture 5.0%, wind south to southwest 7-10 m.p.h.

Brush burning index 15, fire load index 18.

4 p.m.

Temperature 82°, relative humidity 26%, fuel moisture 5.0%, wind south to southwest 8-12 m.p.h., gusts to 15 m.p.h.

Brush burning index 19, fire load index 17.

Fire Behavior:

Burning conditions today depend almost entirely on the wind. Fuels are more moist than yesterday, but hot burns can be expected whenever wind is favorable. If winds fail to materialize, we've had it.

C. Cole, USWB
C. Chandler, USFS